5.0 Other Transportation Applications

- 5.1 GTs used to retard reflective cracking
- 5.2 GCs as erosion control materials (incl. Geotubes and Geocontainers)
- 5.3 GMs for control of expansive soils
- 5.4 GMs for underground storage tanks
- 5.5 GCLs for waterproofing of pavements

5.1 Geotextiles Used to Retard Reflective Cracking

- the major single use of geotextiles (≃ 60,000,000 sq.m/year)
- used primarily for overlays placed cracked or deteriorated asphalt pavements
- concept is to extend life of standard thickness of asphalt overlay, or
- give an equivalent lifetime to a thinner asphalt overlay
- can be used as full width geotextile, or used to cover individual joints

Design Methods for GT

(a) A reinforcement-based design is as follows:

$$FEF = \frac{N_r}{N_n}$$

where

- FEF = the fabric effectiveness factor (2.1 to 15.9 for different GTs)
- N_r = the number of load cycles to cause failure in the geotextile-reinforced case, and
- N_n = the number of load cycles to cause failure in the nonreinforced case

Reinforcement-based design (*cont'd*)

The value can be used in design charts such as those of the Asphalt Institute for the nonreinforced (standard) case and then for the geotextile reinforced case modified as follows:

$$DTN_r = \frac{DTN_n}{FEF}$$

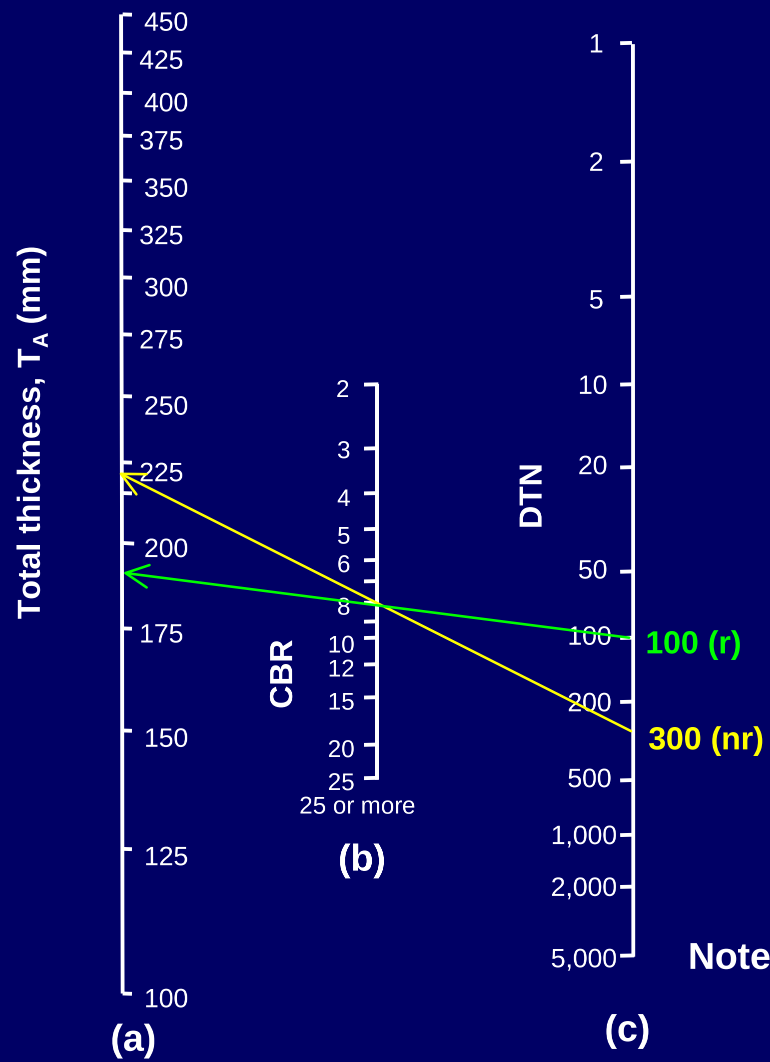
where

DTN_r = the design traffic number in the fabric-reinforced case,
DTN_n = the design traffic number in the non-reinforced case, and
FEF = the fabric effectiveness factor.

The difference between the two cases is the suggested improvement.

Example: reinforcement-based design

Soil CBR = 8 and DTN = 300 without fabric; then repeat problem with FEF = 3, therefore DTN = 300/3 = 100.



for no fabric T_{nr} **= 220 mm**

for FEF = 3 T_r **= 190 mm**

saved asphalt ΔT **= 30 mm**

Note: Chart is based on 20-year design period.

Design Methods for GT *(cont'd)*

(b) A **waterproofing-based design** follows using the representative rebound deflection (RRD) data of a pavement

$$\text{RRD} = \left(\bar{x} + 2s\right)fc$$

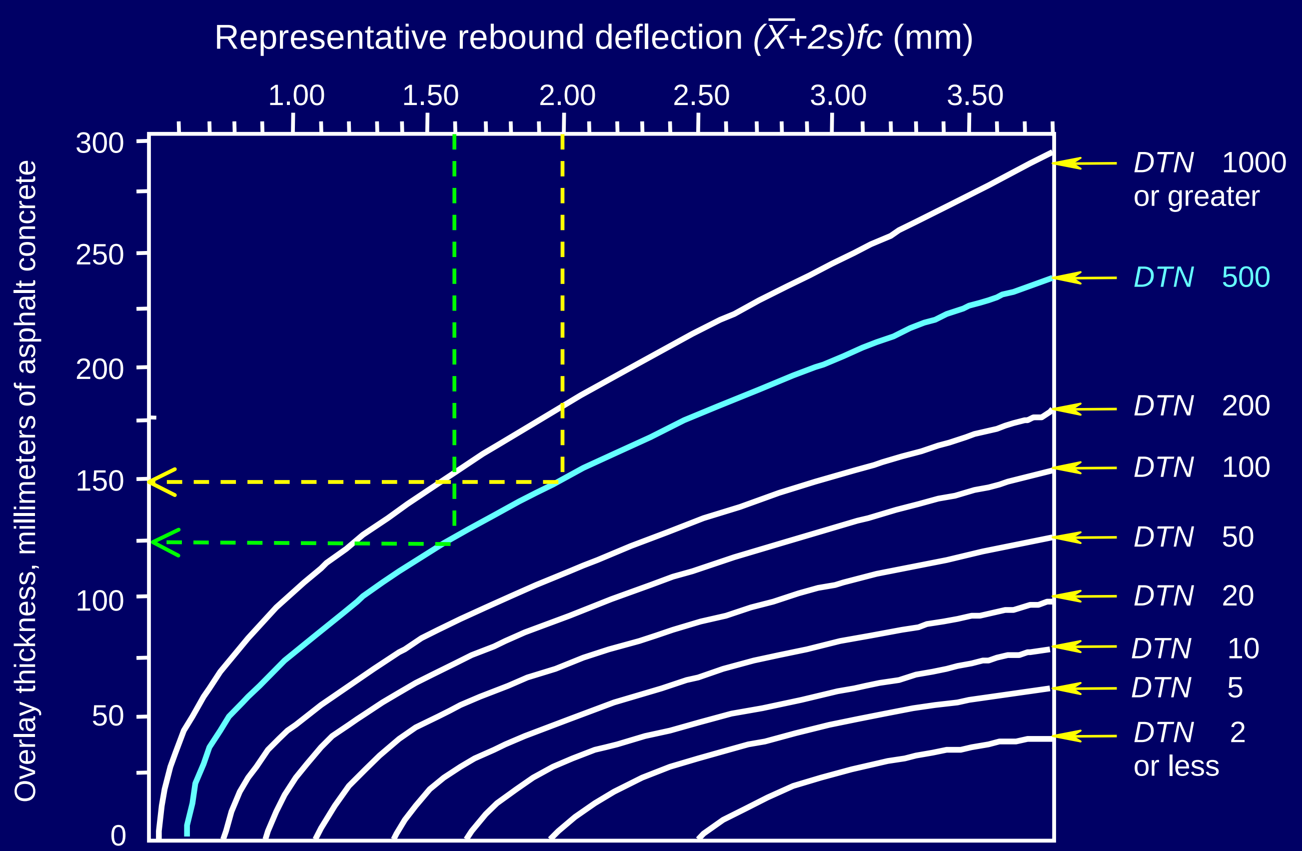
where

- x = the arithmetic mean of measured Benkelman beam values,
- s = the standard deviation,
- f = the temperature adjustment,
- c = critical period adjustment factor, which is largely influenced by moisture in the subgrade system (this is the term that is empirically adjusted using this approach).

The approach can use design charts such as those of the Asphalt Institute for the non-waterproofed case using the conventional value of "c". By then assuming "c" to be the dry subgrade condition (with a properly sealed geotextile) the problem is repeated and the improvement noted.

Example: waterproofing-based design

DTN = 500 and RRD = 2.00 mm without fabric; then repeat problem with RRD = 1.60 mm



for no fabric
T_{nf} = 150 mm

for fabric waterproofing
T_f = 120 mm

saved asphalt
ΔT = 30 mm

Design Methods for GT *(cont'd)*

(c) a crack propagation rate design for GTs (both low & high strength) and for GGs

- **concept follows work of Molenaar at Delft University in Holland using a power law**

- **dc/dN = crack propagation rate**

$$\frac{dc}{dN} = AK^{n}$$

where

A, K, n are experimentally obtained

- **see example following**

Example: crack propagation rate design

100 mm overlay on cracked pavement with 100,000 cycles/yr. $K = 10$ N/mm$^{1.5}$; $A = 1.0 \times 10^{-8}$; $n = 4.3$. Calculate number of lifeyears for no reinforcement, then for a nonwoven GT, then for GGs of different strengths.

Solution:

reinforcement	A	life cycles	life years
None	1.0×10^{-8}	500,000	5
GT-NW	0.5×10^{-8}	1,000,000	10
GG-PP	0.35×10^{-8}	1,400,000	14
GG-PET	0.33×10^{-8}	1,500,000	15
GG-FG	0.25×10^{-8}	2,000,000	20

Comment: Example is hypothetical; constants need field verification; concern over scale effects of lab tests; much work to be done; other approaches are possible; but this method is of considerable interest

Comments on GTs in Reflective Cracking

- mechanism is not clear
- topic needs carefully instrumented field sites
- works good in warm climates, poor in cold climates, mixed results between
- thermal cycling appears to be a problem with lightweight geotextiles
- current thrust is with geogrids and fiberglass geotextiles over full width and strip reinforcement over joints in concrete pavements

5-Year Test Results
Paris, Maine via Maine DOT

Transverse Joints - % Crack Reflected

Control	Strip. Rein.	Improvement
77.8	10.7	7.3
85.4	19.0	4.5
96.7	32.2	3.0
100	43.3	2.3
100	46.6	2.1
		Ave. = 3.8, i.e., 380%

5-Year Test Results
Paris, Maine via Maine DOT *(cont'd)*

Longitudinal Joints - % Crack Reflected

Control	Strip. Rein.	Improvement
1.2	0.3	4.0
1.2	0.3	4.0
7.0	1.5	4.7
8.1	6.6	1.2
17.1	7.4	2.3
		Ave. = 3.2, i.e., 320%

5.2 Geocomposite Erosion Control Materials (modified from Theisen, IECA)

- **Temporary Erosion and Revegetation Materials (TERMs)**

Straw, hay and hydraulic mulches
Tackifiers and soil stabilizers
Hydraulic mulch geofibers
Erosion control meshes and nets (ECMNs)
Erosion control blankets (ECBs)
Fiber roving systems (FRSs)

- **Permanent Erosion and Revegetation Materials (PERMs)**
  - Biotechnical Related

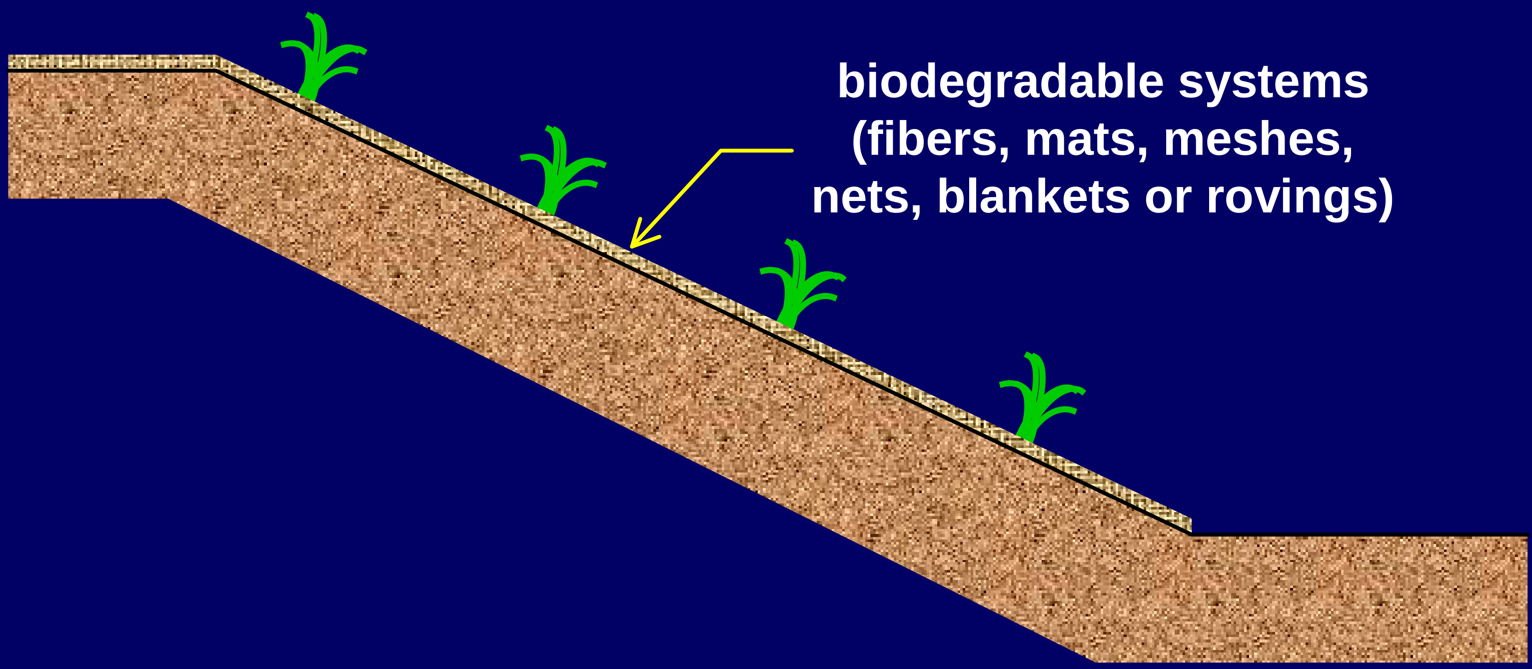
UV stabilized fiber roving systems (FRSs)
Erosion control revegetation mats (ECRMs)
Turf reinforcement mats (TRMs)
Discrete length geofibers
Vegetated geocellular containment systems (GCSs)

- **Permanent Erosion and Revegetation Materials (PERMs)**
  - Hard Armor Related

Geocellular containment systems (GCSs)
Fabric formed revetments (FFRs)
Vegetated concrete block systems
Stone rip rap
Gabions

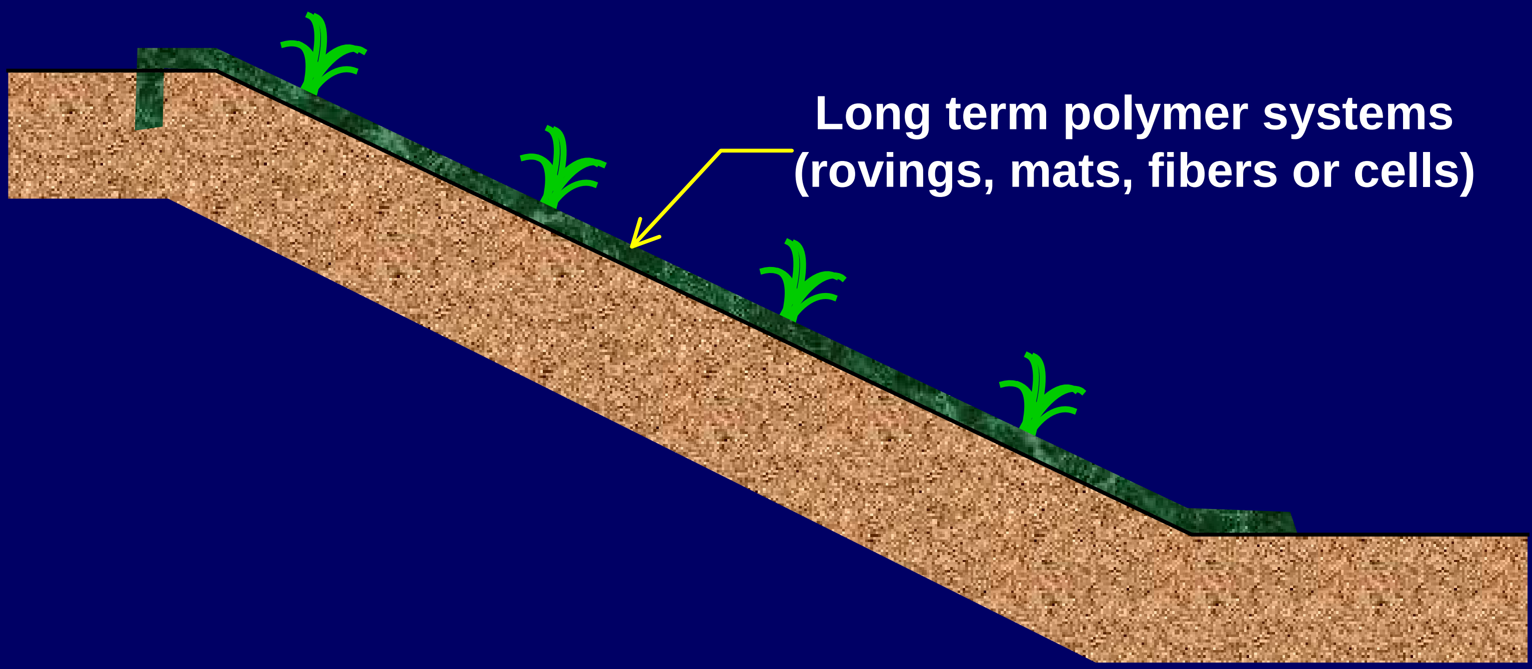
Geosynthetic Erosion Control Materials

(a) Temporary Erosion and Revegetation Materials (TERMs)



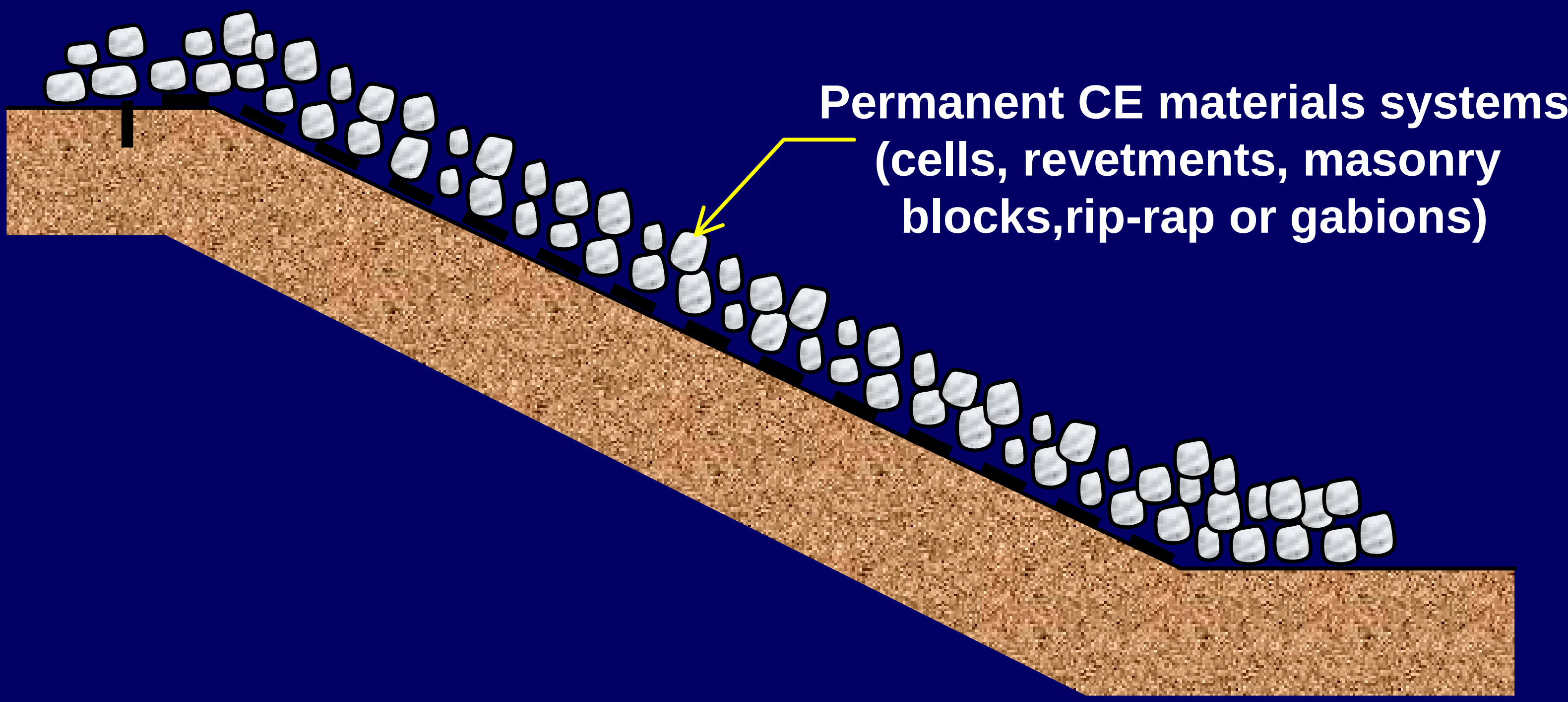
Geosynthetic Erosion Control Materials *(cont'd)*

(b) Permanent Erosion and Revegetation Materials (PERMs) - Biotechnical Related

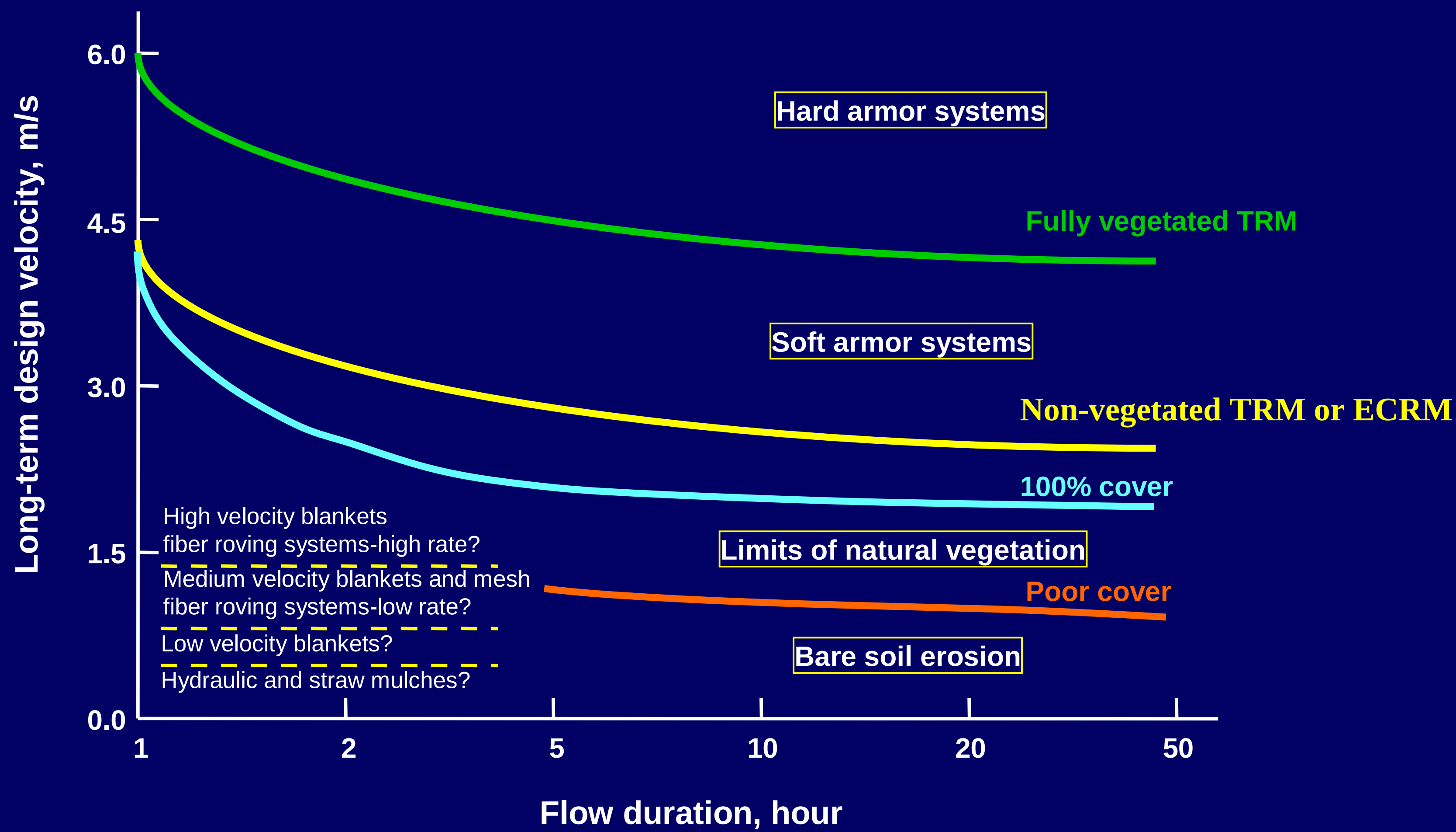


Geosynthetic Erosion Control Materials *(cont'd)*

(c) Permanent Erosion and Revegetation Materials (PERMs) - Hard Armor Related



Recommended maximum design velocities for various classes of erosion control materials (after Theisen)

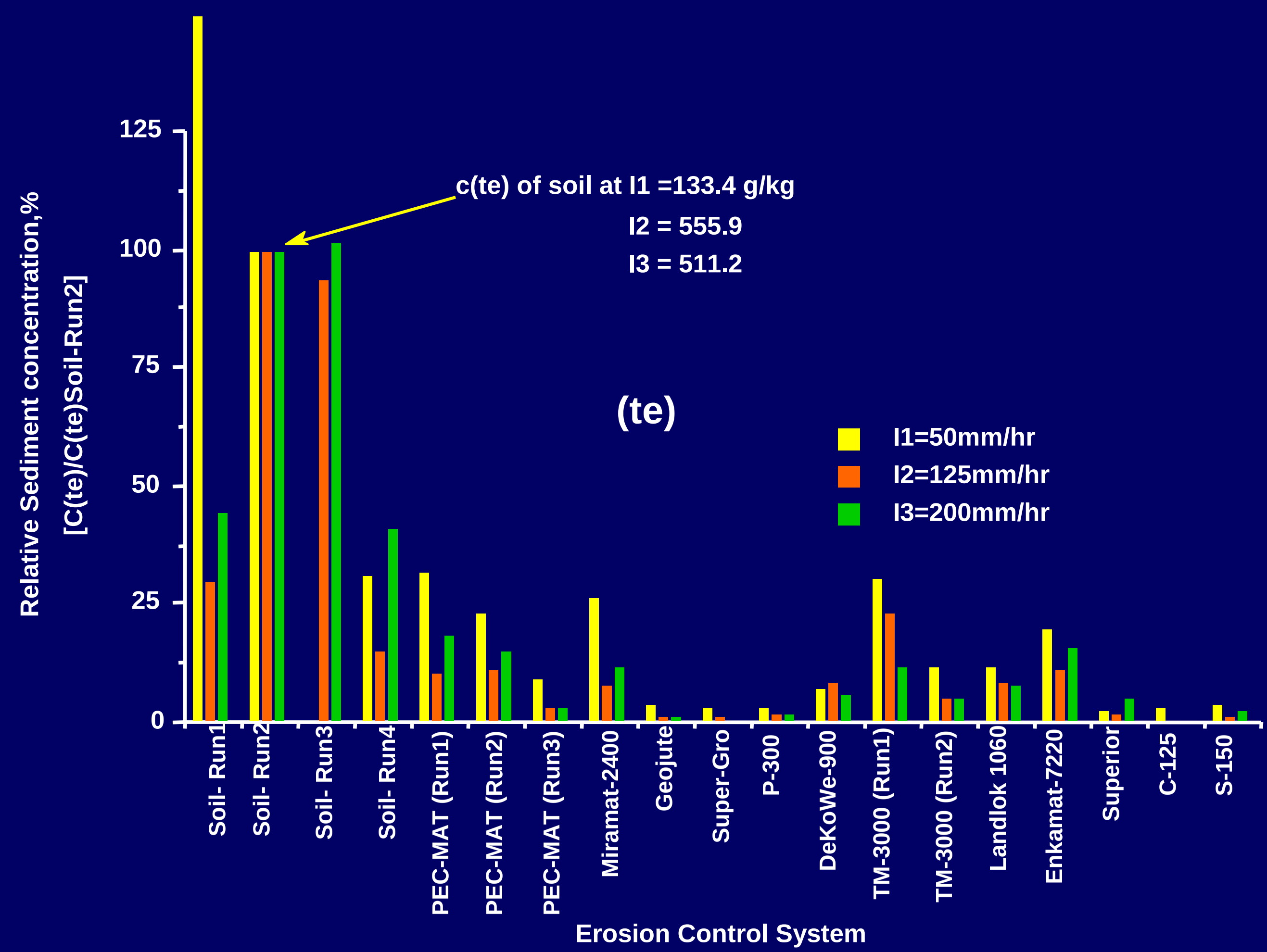


Comments on Erosion Control Materials

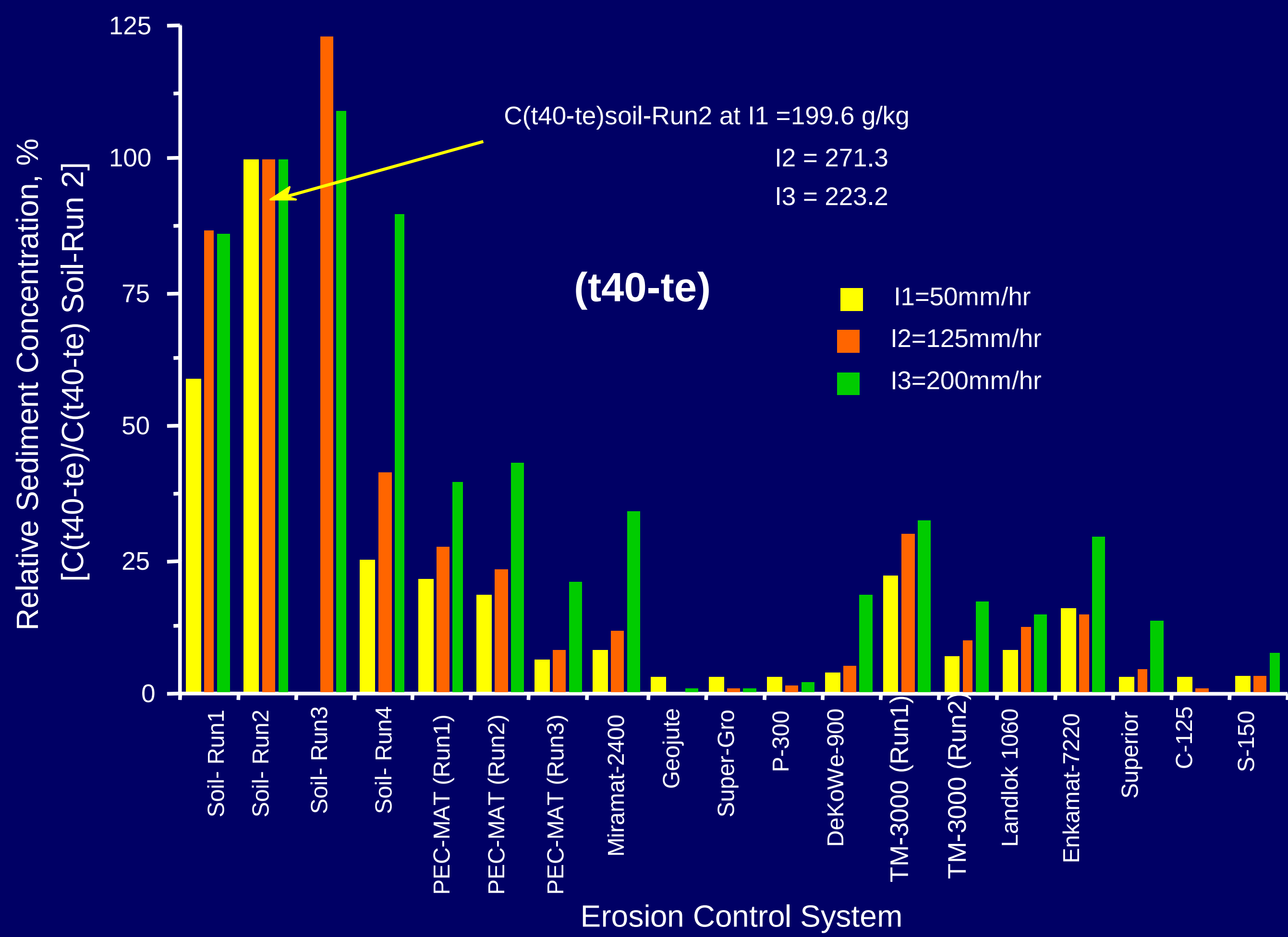
- flexibility is a key feature
- intimate contact to soil subgrade is essential
- no available design to distinguish between products within each category
- index test methods are available
- performance test methods are being developed
- many field trials are ongoing
- some laboratory data is available, see following

Laboratory soil erosion test results

(after Rustom and Weggel, 1993)

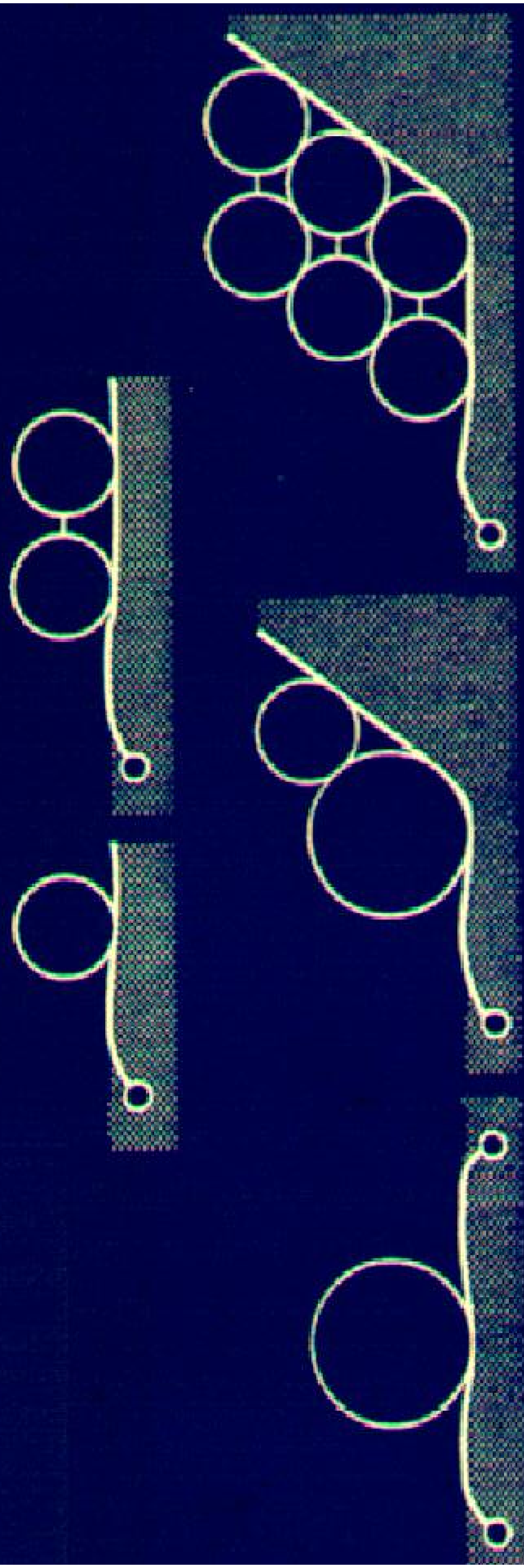


Laboratory soil erosion test results *(cont'd)*
(after Rustom and Weggel, 1993)



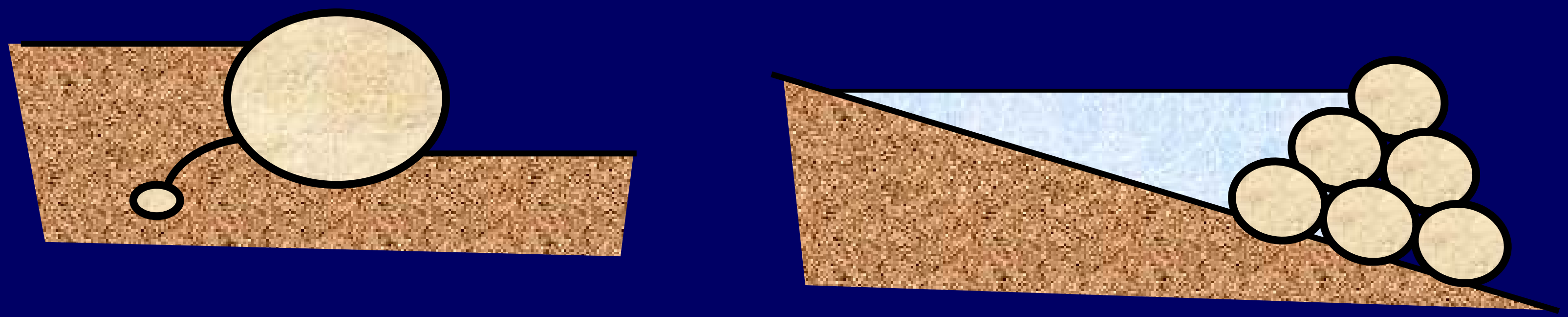
Geotubes

- large diameter tubes (up to 4-m) made from high strength geotextiles
- experiments ongoing with lower strength nonwoven geotextiles
- slurry filled with sand, sludge, flyash, etc.
- used to prevent beach and slope erosion



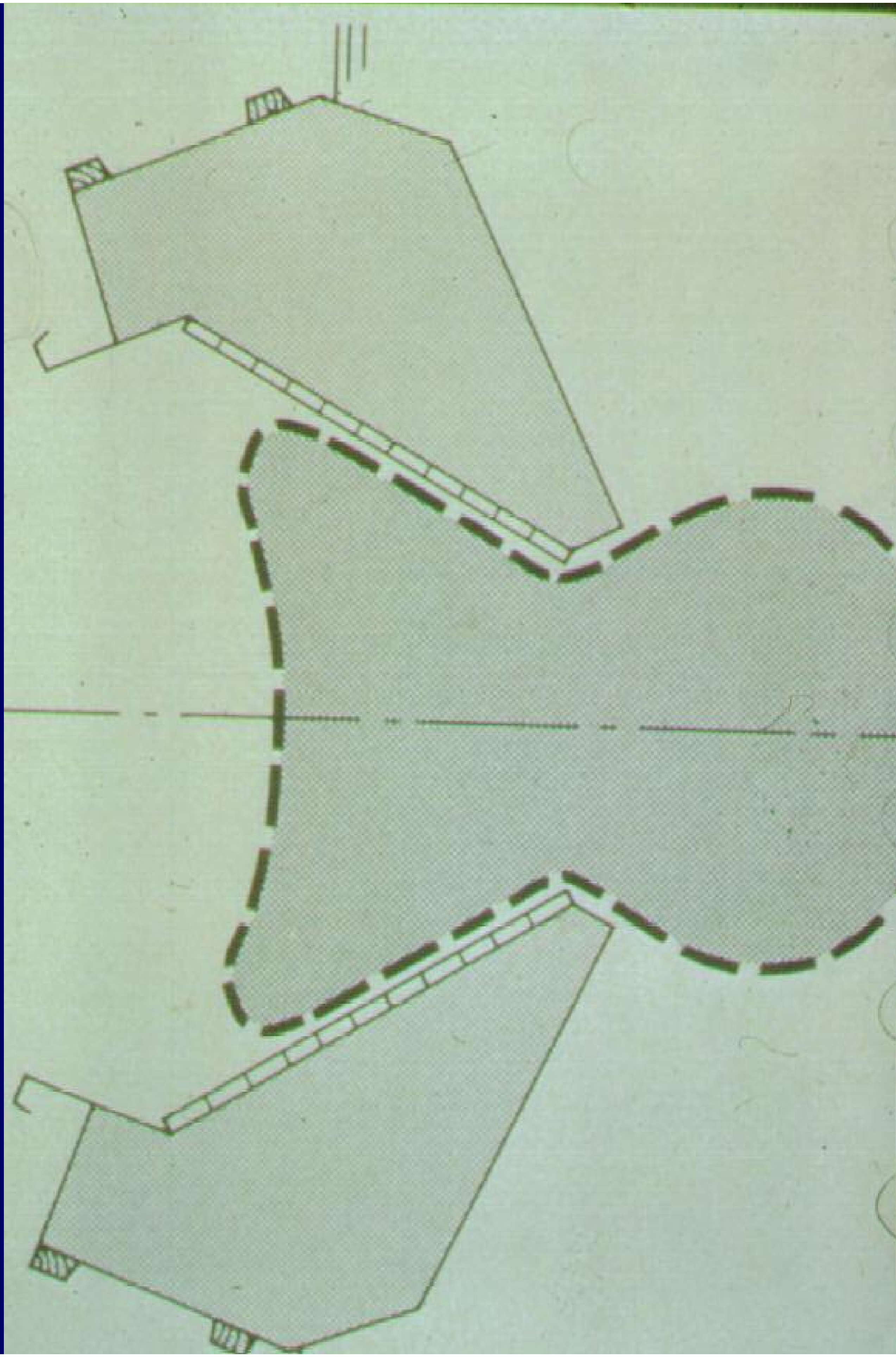
Geocontainers

Harbor/river dredged soil forming underwater storage



(a) typical

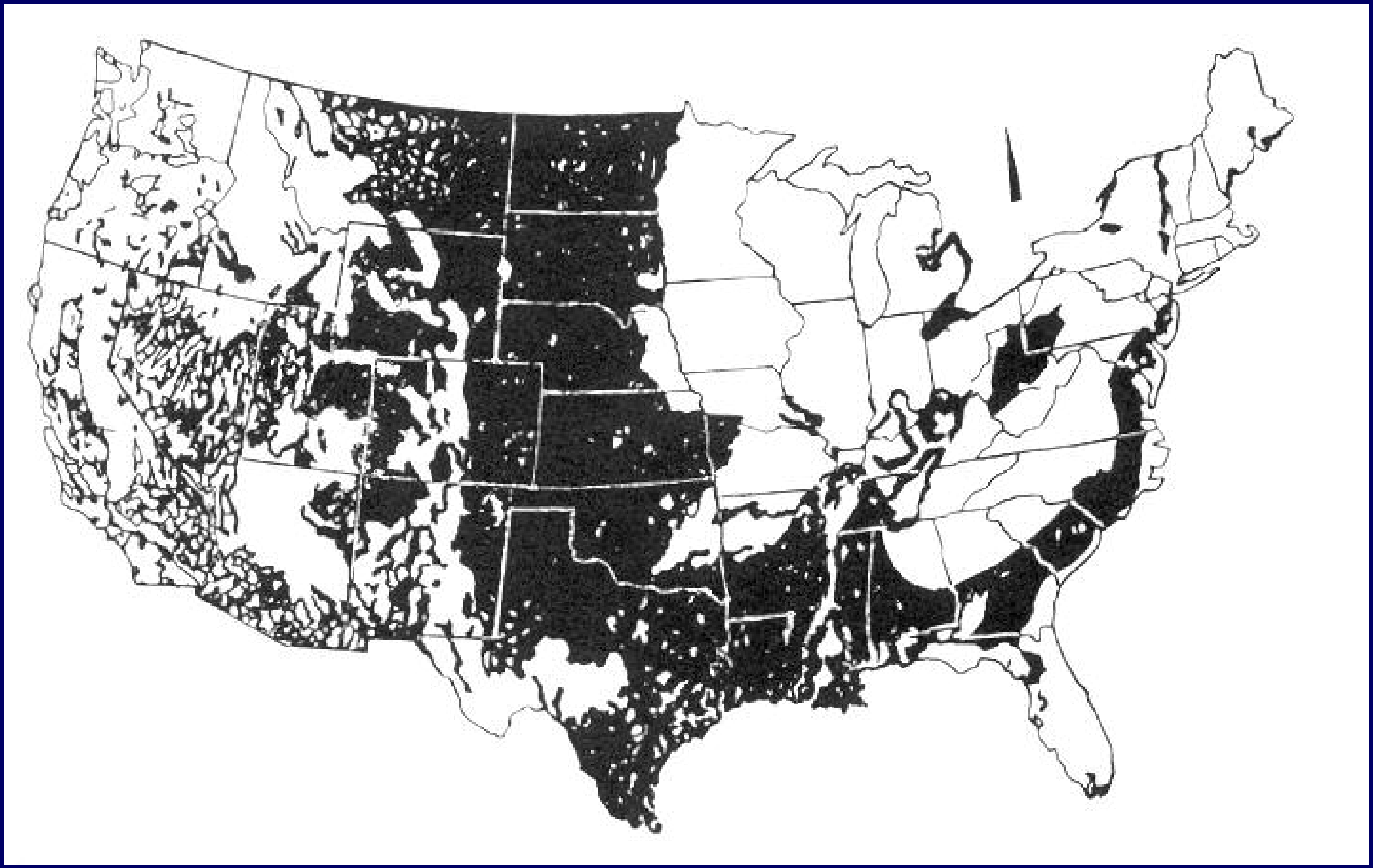
(b) possible



5.3 Geomembranes for Control of Expansive Soils

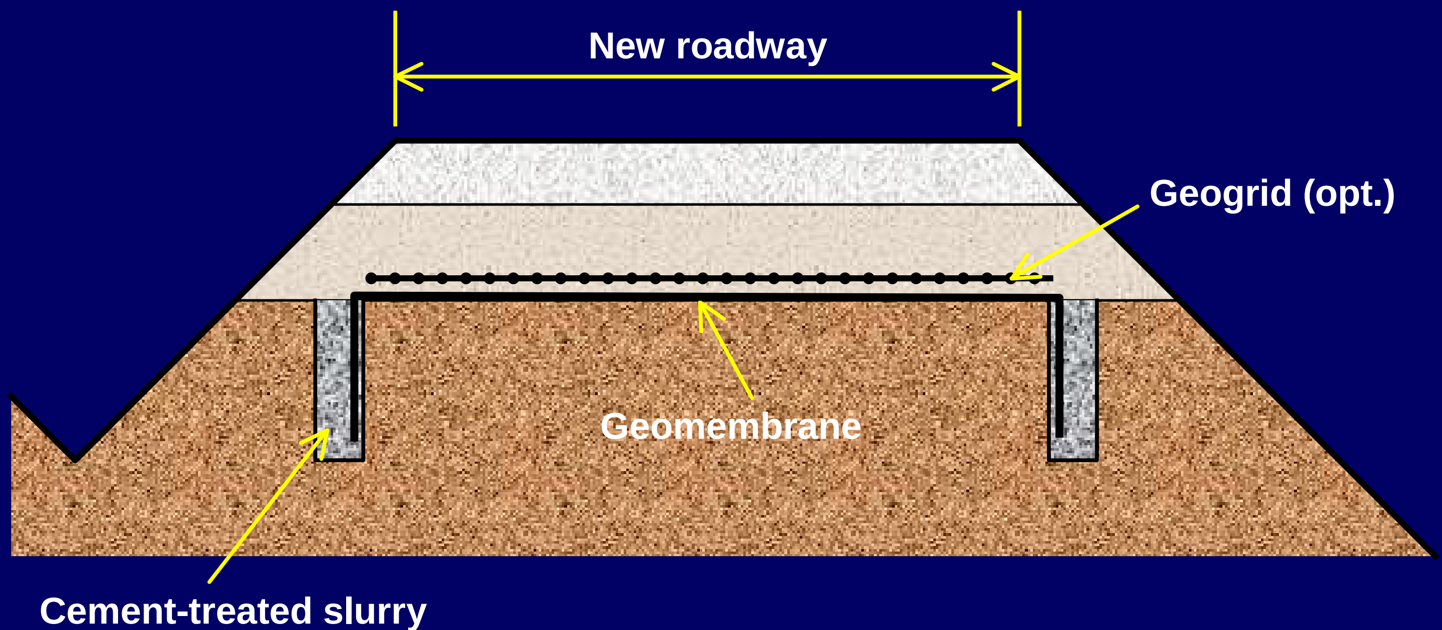
- also called swelling clays, shrinking soils and expansive shales
- deformations caused by variation in soil moisture content: moves everything either vertically or laterally
- damage estimated at $10B in U.S. - even greater worldwide

Expansive soils in the United States



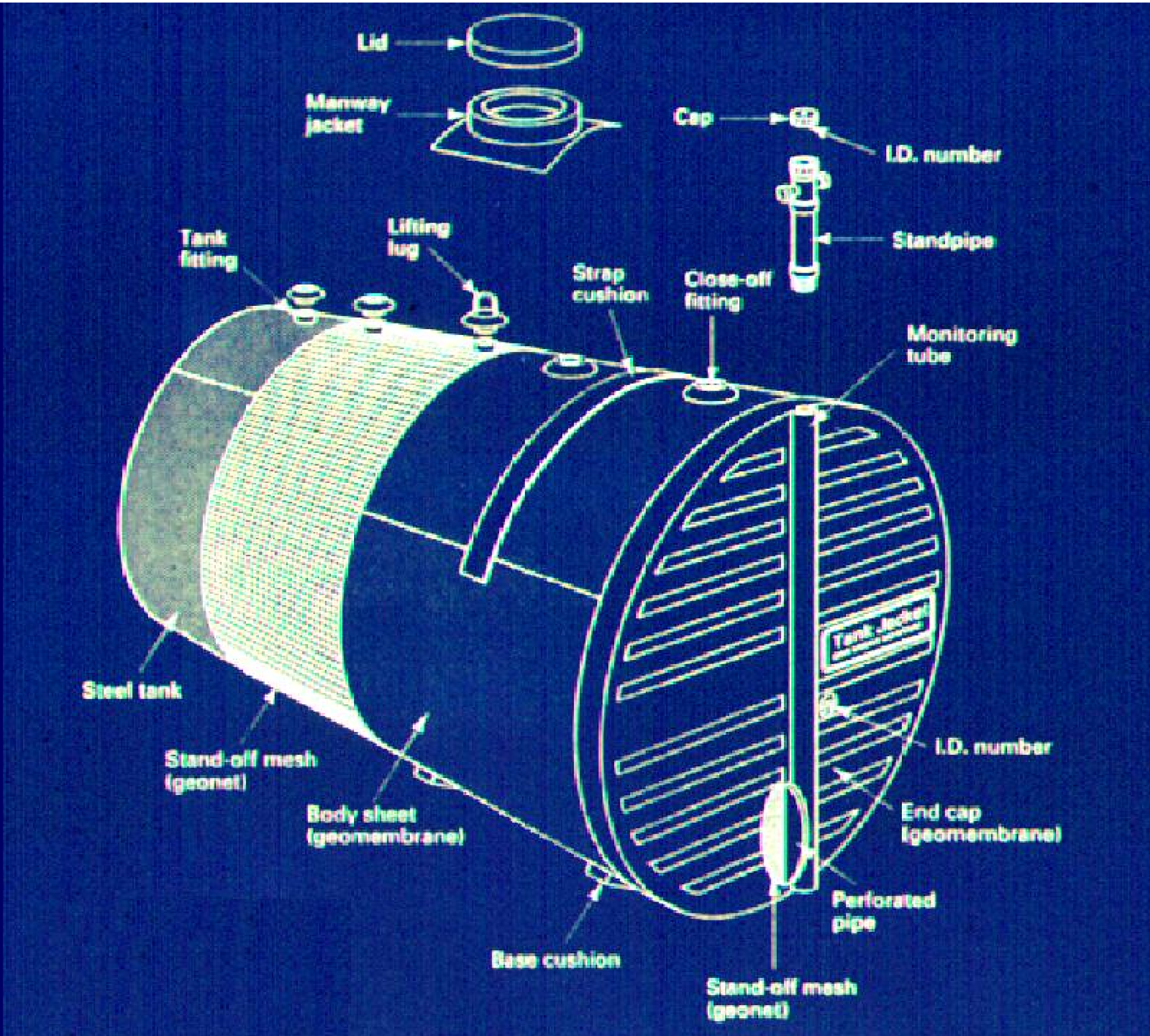
Various GM Configurations
(ref. M. Steinberg, McGraw Hill, 1998)

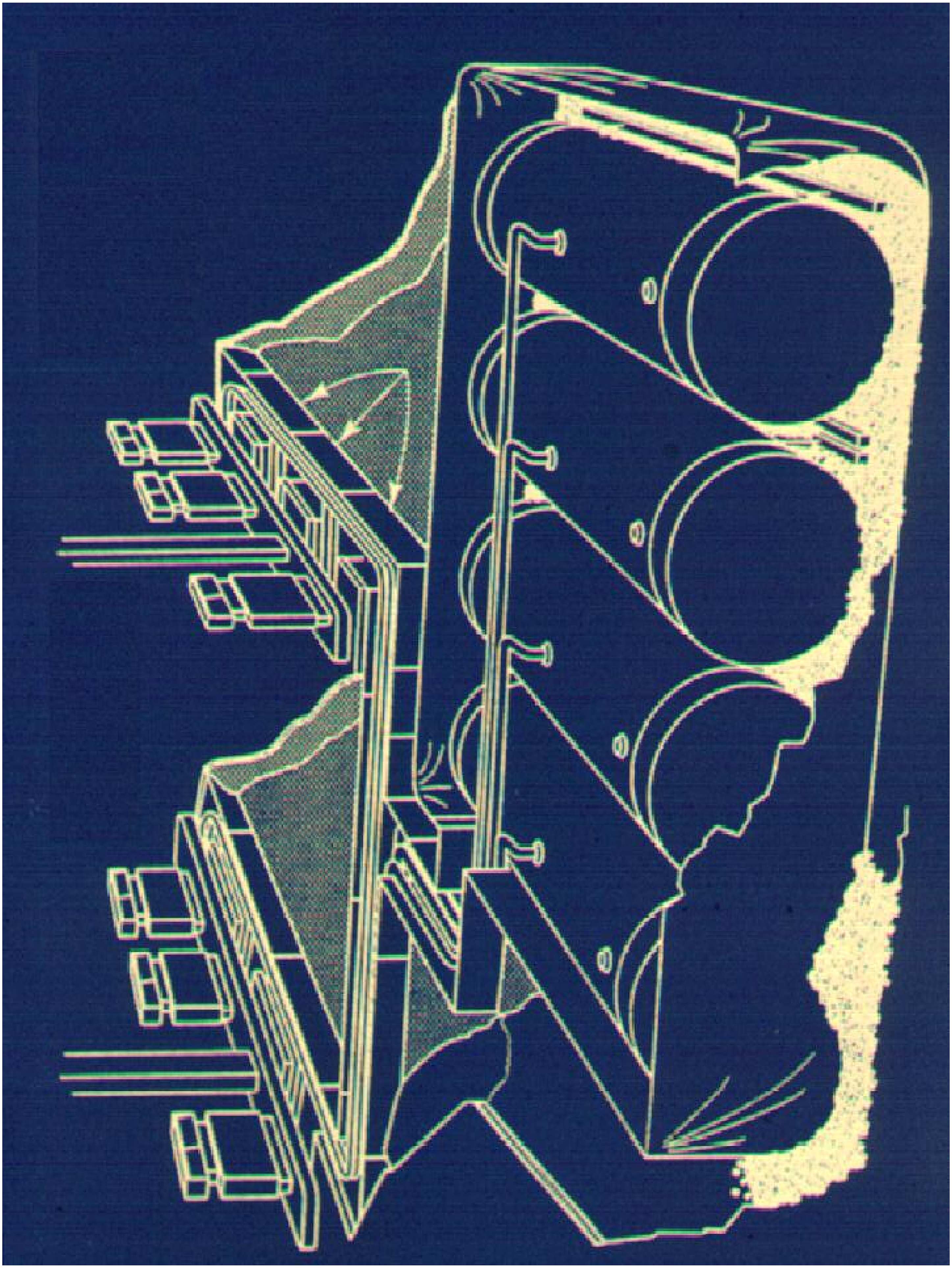
Goal: prevent vertical and lateral moisture migration from expansive clay subgrade soil

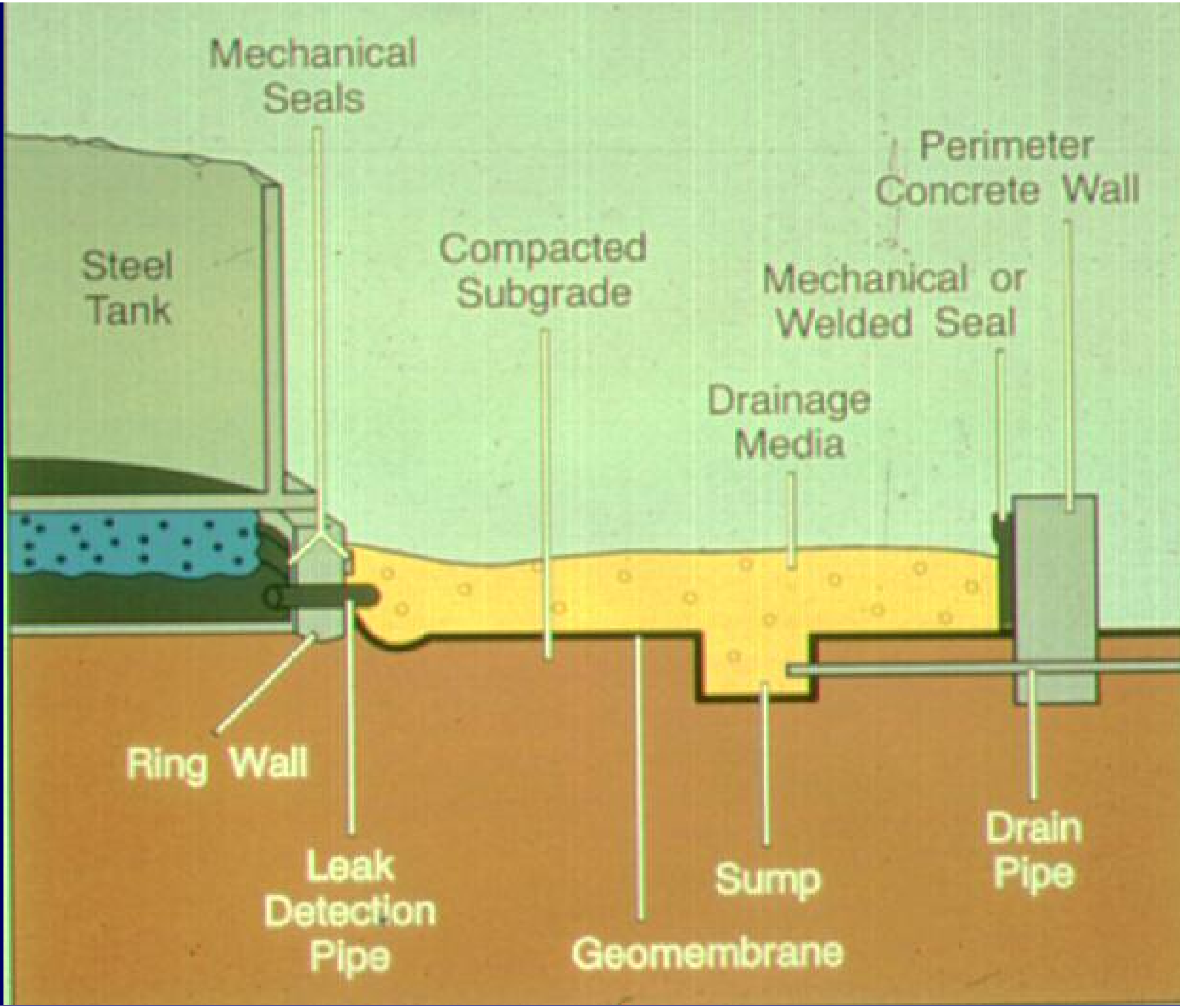


5.4 Geomembranes for Underground Storage Tanks (UST)

- secondary containment required in approximately 24 states in the U.S.
- two strategies using GMs
  - tank/geonet/geomembrane
  - tank/gravel/geomembrane
- geomembranes most commonly used are EIA-R and HDPE (best chemical resistance to hydrocarbons)
- GCLs can be used providing they are first hydrated with water


Lid
Manway jacket
Cap
I.D. number
Standpipe
Tank fitting
Lifting lug
Strap cushion
Close-off fitting
Monitoring tube
Steel tank
Stand-off mesh (geonet)
Body sheet (geomembrane)
I.D. number
End cap (geomembrane)
Perforated pipe
Base cushion
Stand-off mesh (geonet)





Mechanical Seals
Steel Tank
Compacted Subgrade
Perimeter Concrete Wall
Mechanical or Welded Seal
Drainage Media
Ring Wall
Leak Detection Pipe
Geomembrane
Sump
Drain Pipe

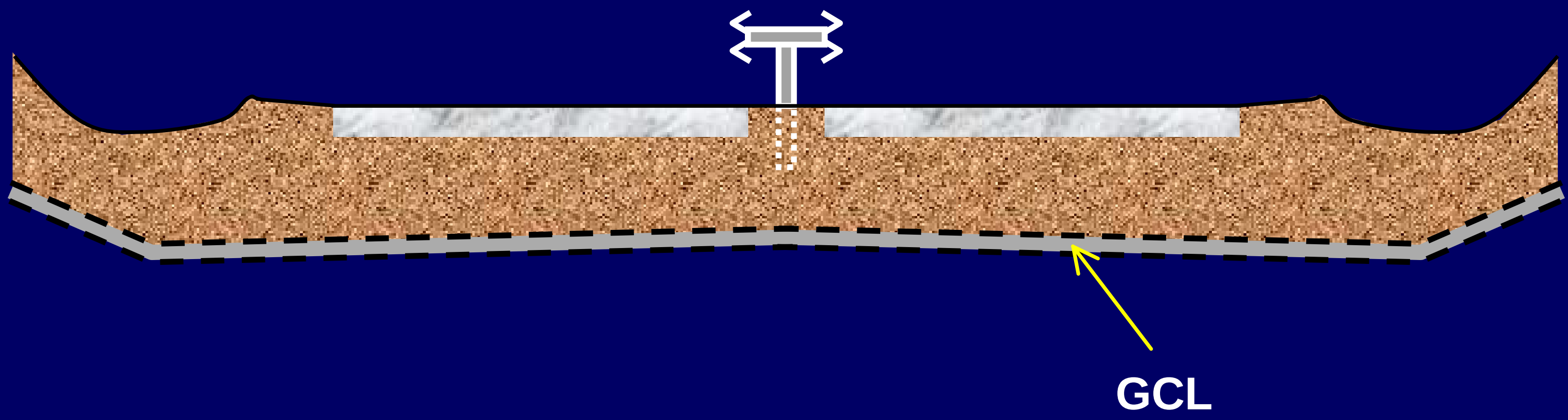
5.5 GCLs for Waterproofing of Pavements

- thin bentonite layers sandwiched between geotextiles or bonded to a geomembrane
- factory manufactured and shipped to job site in rolls
- can be used for underground storage facilities, bridge decks, tunnels, and in general waterproofing applications

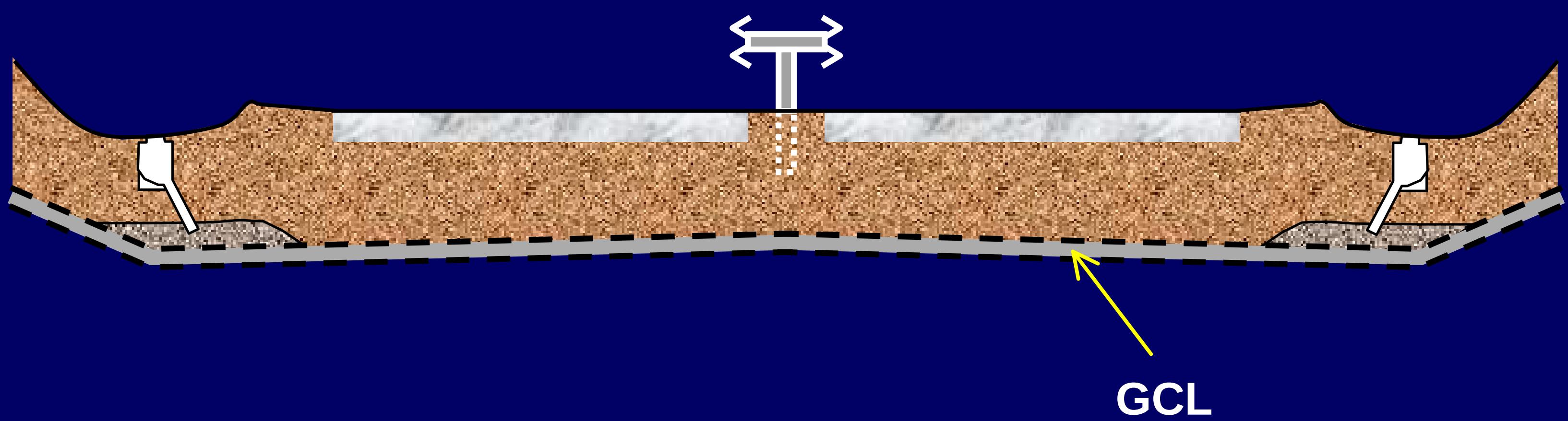
Applications

- Airfields
  - to contain de-icing chemicals, e.g., glycol
  - example, new Munich Airport
- Highways
  - to contain salts from entering waterways
  - to contain oil and chemical spills
  - example, Autobahn A96 in Germany
  - to prevent water from generating sinkholes
  - example, PennDOT Rt. 202 near Philadelphia

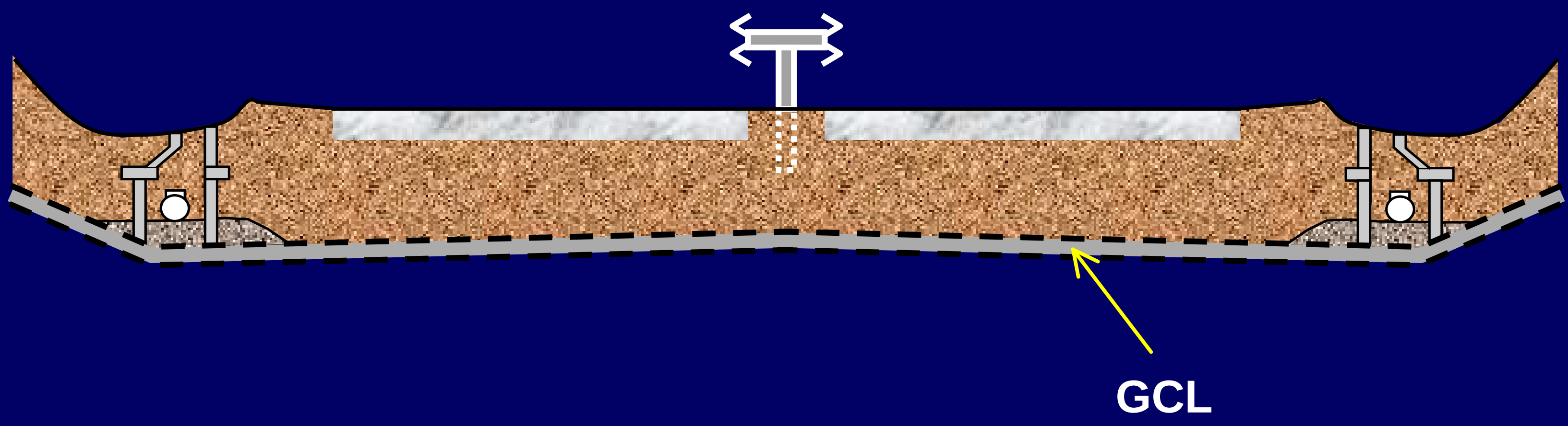
(a) Basic barrier system



(b) Removal on demand system



(c) Automatic removal system



End of Section 5